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ADULT AND LARVAL LAMPREY EELS  
OF CAYUGA LAKE.

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## THE FORM AND SIZE OF THE RED BLOOD-CORPUSCLES OF THE ADULT AND LARVAL LAMPREY EELS OF CAYUGA LAKE.\*

SIMON HENRY GAGE, B.S.

As the red blood-corpuscles of the camelidæ form an exception in the great mammalian group in being oval instead of circular in outline, and, according to Gulliver (3),† in not forming distinct rouleaux, or rolls, so the red corpuscles of the lamprey eels form an exception in the great non-mammalian group of vertebrates (birds, reptiles, and fishes) in being *bi-concave* and *circular*, instead of *oval* and *bi-convex*, like those of all the other animals in this great group. The corpuscles also agree with those of mammals in forming distinct rouleaux. This is most marked in the brook lamprey and the larva. In the 9 mm. embryo the corpuscles were often seen in rolls of three or four in the circulating blood (Fig. E. F.) Rouleaux have also been observed in the vessels of a living dog's mesentery (19). A nucleus is present in all the corpuscles, but as it is small and placed in the thickest

\* Following Jordan and Gilbert (Synopsis of the Fishes of North America, 1882), the adult lampreys are called sea lamprey (*Petromyzon marinus*) and brook lamprey (*Ammocetes branchialis*). The name *Ammocetes* was originally applied to the larval condition, supposing it to be a distinct animal and not merely a larva. All the specimens from which blood was taken were obtained in May and June in the streams flowing into the head of Cayuga Lake. The smallest larvæ (embryos 9 mm. long) were taken from the nest of the sea lamprey. The larger larvæ were dug out of a sand-bank along the stream; it is not known whether they are the young of the sea or of the brook lamprey.

† The numbers in parentheses refer to the bibliography at the end of the paper.





part of the corpuscle, it is not apparent in the perfectly fresh corpuscles, except faintly in some of those of the 9 mm. embryo. The corpuscles when fresh appear, therefore, almost exactly like those of man. No element of uncertainty should arise with respect to them in legal medicine, however, for (*a*), the presence of a nucleus may be readily demonstrated, as it is made apparent by drying, by acetic acid, and by the reagents most used in examining blood for medico-legal purposes; (*b*), except in the embryo, 9-10 mm. long, the corpuscles are nearly twice as large as those of man. (Compare the accompanying table of measurements). Hence the blood corpuscles of lamprey eels, in spite of their bi-concave form and circular outline, really offer no more difficulty in medical jurisprudence than do the corpuscles of any other of the non-mammalian vertebrates.\*

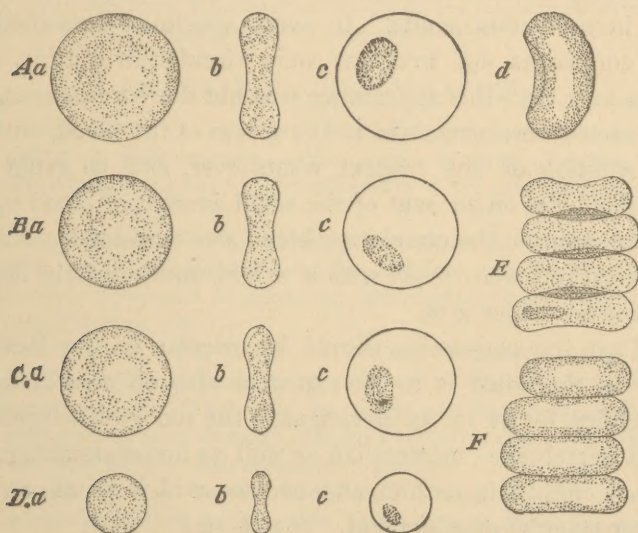
The circular outline of the red blood-corpuscles in both adult and larval lampreys was discovered by R. Wagner and the fact published in 1838 (18). The bi-concave character is remarked upon by Wagner, Kölliker, and others, but I have seen no reference to the fact that the corpuscles form distinct rouleaux like those of mammals.

Although the bi-concave character of the corpuscles of lampreys is as easily demonstrated as in the corpuscles of mammals, it is stated by Gulliver and Günther (4 and 5) that they are flat or bi-convex, and Gegenbauer (2), in his Comparative Anatomy, states that the red blood-corpuscles of birds, reptiles, amphibia, and fishes are bi-convex, no exception being made for the lampreys. Parker (15) in his translation of Wiedersheim's Comparative Anatomy of the Vertebrates, says: "In case of the red corpuscles, the nucleus persists, and the whole cell is bi-convex in all vertebrates below mammals." In 1887 wide circulation was given to a

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\* While it is true that the red corpuscles of mammalian embryos and the developing corpuscles in the adult are nucleated, the size and uniformly nucleated condition of the corpuscles of the lamprey would sufficiently characterize them.

statement by Shipley (16), and Thompson (17), that the red blood corpuscles of larval lampreys were oval in outline, like the rest of the non-mammalian vertebrates, and came to be circular only in the adult.



Figures of the red blood-corpuscles of adult and larval lamprey eels, showing the appearance in different positions and the relative size in the different animals. Magnified 1,000 diameters. Outlined with Abbe's camera lucida. Drawn by Mrs. Gage. From the *New York Medical Journal*.

A. Red blood-corpuscles of the sea lamprey (*Petromyzon marinus*). *a*, face view of a corpuscle; *b*, optical section of a corpuscle on edge; *c*, face view of a corpuscle, showing the nucleus after the action of one per cent. acetic acid; *d*, cup-shaped corpuscle.

B. Red blood-corpuscles of the brook lamprey (*Ammocetes branchialis*). *a*, *b*, *c*, the same as in A.

C. Red blood-corpuscles of a larval lamprey 142 mm. long. *a*, *b*, *c*, as in A.

D. Red blood-corpuscles of a larval or embryo lamprey 9 mm. long. *a*, *b*, *c*, the same as in A.

E. Rouleaux of the corpuscles of the brook lamprey in optical section. In the lower corpuscle a nucleus is indicated to show that it is small and in the thickest part of the corpuscle. It is visible only after the hæmoglobin is partly or wholly removed from the corpuscle. In the embryo, where the corpuscles are so small, the nucleus is faintly visible in many corpuscles before the removal of the hæmoglobin.

F. Rouleaux of the 142 mm. larva focused on the upper surface. In both E. and F. the corpuscles are shown of different sizes. Compare the maximum and minimum diameters in the table of measurements.

That the red blood-corpuscles of both the adult and larval lampreys inhabiting Cayuga Lake are circular, bi-concave, nucleated discs, as described and figured in this paper, was repeatedly demonstrated in larvæ from 9 to 142 mm. long, and in numerous adults. In every specimen examined all the corpuscles not irregular were circular in outline. To make sure that this appearance was not due to reagents, the corpuscles were examined in the serum of the blood, without the addition of any reagent whatsoever, and to avoid any possible error on account of the small amount of blood in the 9 mm. embryo, the circulating blood was examined. All the examinations were made with a 2 mm. apochromatic objective and an ocular  $\times 12$ .

That the corpuscles should be circular in the larva as well as the adult is to be expected also on morphological principles, for as far as investigated the red blood-corpuscles of all vertebrates, mammalian as well as non-mammalian, are at first circular in outline, and become oval, if at all, only at a later stage of development. (12, 8, 10.)

Table showing the diameter and thickness of the red blood-corpuscles of the lampreys in the adult and larval condition; also the relative number of red and white corpuscles, and the number of red corpuscles in a cubic millimeter of blood.\*

	DIAMETER.			Thick- ness.	Ratio of thickness to diameter	Ratio of white to red corpuscles.	No of red corpus- cles in a cubic millimetre.
	Maxi- mum.	Mini- mum.	Aver- age.				
<i>Petromyzon</i> <i>marinus</i> ,	16.16 $\mu$	10.1 $\mu$	14.2 $\mu$	5.05 $\mu$	1 : 2.8	Male, 1 : 20 Female, 1 : 15	Male, 391,333 Female, 334,666
<i>Ammocetes</i> <i>branchialis</i> ,	15.15 $\mu$	10.1 $\mu$	13. $\mu$	5.02 $\mu$	1 : 2.59	1 : 95	500,000
Larval lam- prey 142 mm. long,	15.65 $\mu$	12.12 $\mu$	13.4 $\mu$	3.48 $\mu$	1 : 3.8	1 : 10	Not determined.
Embryo lam- prey, 9 mm. long,	8. $\mu$	7. $\mu$	7.448 $\mu$	1.96 $\mu$	1 : 3.8	1 : 10	Not determined.

\* In a larva 73 mm. long, the average diameter was 12.44  $\mu$  — that is, 0.96  $\mu$  smaller than in the larva of 142 mm. given in the table. Gulliver (4, p. 845) states that "there is little difference between the blood-corpuscles of *Petromyzon*



NOTE. — The blood for measurement was taken from the heart or a pithing wound, and mounted without the addition of any liquid. The cover-glass was supported by a hair and sealed with castor oil. Only undistorted corpuscles were measured. The averages were obtained from twenty-five measurements in each case. All measurements were made with a 2 mm. apochromatic objective and C. ocular containing a Jackson ocular micrometer, the value of which was determined by using a Rogers standard stage micrometer.

### ANNOTATED BIBLIOGRAPHY.

1. *Gage, Simon H.*—The Red Blood-Corpuscles of Lamprey Eels in Relation to Jurisprudence. *New York Medical Journal*, Vol. XLVIII (1888), pp. 149-150. The main facts of the present paper were given.

2. *Gegenbauer, C.*—The Elements of Comparative Anatomy, London, 1878. "In fishes, amphibia, reptiles, and birds, they [the red blood-corpuscles] are oval and *bi-convex*, for the center of each surface protrudes slightly." p. 576.

3. *Gulliver, G.*—The Works of William Hewson. London, 1846. Note CIX (p. 228), non-formation of rouleaux by the red corpuscles of the camels. Note CXVII: "In the cyclostomes the corpuscles are of the same figure as those of man's, and only slightly larger." See under 13 for the oval form of the corpuscles in myxine.

4. *Gulliver, G.*—On the Red Blood-Corpuscles of Vertebrates. Proceedings Zoölogical Society, 1862, p. 99; 1870, p. 844; 1875, p. 474. Gives an excellent account of the blood-corpuscles in all groups of vertebrates, and says (1870, p. 844): "The red corpuscles of the lamprey are but rarely or exceptionally bi-concave discs, and then only from irregular or unequal depressions on the surfaces, scarcely ever from two symmetrical concavities. . . . On the contrary, the red blood-corpuscles of the lamprey are regularly either flat or slightly bi-convex." This characterization does not hold for the corpuscles of the American lampreys examined. The red corpuscles are many of them distorted, however.

5. *Günther, A. C. L. G.*—An Introduction to the Study of Fishes.

*planeri*, *P. fluviatilis*, and *Ammocetes branchialis* [the larval form]; that one description may serve for all three of them"; and gives the following measurements: Diameter of the red corpuscles, 11.9  $\mu$ ; thickness, 4.09  $\mu$ ; diameter of nucleus, 3.96  $\mu$ . Kölliker (9) gives 11.3  $\mu$  as the size, not mentioning the species or the age. Welcker (20) gives 15  $\mu$  as the average size of the red corpuscles of *Petromyzon marinus*, with a maximum of 16  $\mu$  and a minimum of 13.4  $\mu$ . Thickness of the corpuscles, 3  $\mu$ . For the larva the average is 11.7  $\mu$ , with a maximum of 12.4  $\mu$  and a minimum of 10.9  $\mu$ . Thompson (17) gives the size of the red corpuscles of *Petromyzon marinus* as 13  $\mu$  to 14  $\mu$ . He says also that the number of white corpuscles is three or four times as great as the red ones. Welcker gives the number of red corpuscles in a cubic millimetre of the blood of *P. marinus* as 133,000.

Edinburgh, 1880. In this and the following it is stated that the corpuscles of lampreys are flat or *bi-convex*. "The blood-corpuscles of fishes, with one exception, are of elliptical shape; this exception is *Petromyzon*, which possesses circular, flat, or slightly bi-convex blood-corpuscles."

6. *Günther, A. C. L. G.*—Article, Ichthyology, Encyclopædia Britannica, 9th ed., vol. 12, p. 658.

7. *Huxley, T. H.*—A Manual of the Comparative Anatomy of Vertebrated Animals. New York, 1873. The red blood-corpuscles in the marsipobranchii are circular and nucleated. All other fishes have oval corpuscles. p. 90. See under 13 for myxine.

8. *Jones, Wharton.*—The Blood-Corpuscle Considered in its Different Stages of Development. Philosophical Transactions, 1846. Says the blood-corpuscles of lampreys are circular at all stages of development. p. 66.

9. *Kölliker, A.*—Handbuch der Gewebelehre des Menschen. Fünfte umgearbeitete Auflage. Leipzig, 1867. Also, his Manual of Human Histology, translated and edited by Busk and Huxley, 1853-4. Says, p. 629, German, Vol. II, p. 336, English, that the corpuscles of petromyzon and myxine are circular and bi-concave. See under 13 for myxine.

10. *Kölliker, A.*—Grundriss der Entwicklungsgeschichte, 2d ed., 1884. Says corpuscles of the chick are, in the course of development, first circular. p. 63.

11. *Leydig, F.*—Traite d' Histologie de l' Homme et des Animaux. Paris, 1866. Says, p. 507, that the red corpuscles of myxine and petromyzon are circular and bi-concave. See under 13 for myxine.

12. *Milne-Edwards, H.*—Leçons sur la Physiologie et l' Anatomie de l' Homme et des Animaux. 14 vols. Paris, 1857-1880. Says, in Vol. I, p. 62, that only the circular corpuscles form distinct rouleaux. In the corpuscles of all non-mammalian vertebrates, the corpuscles are, in the course of development, at first circular, probably circular in the camelidæ also, p. 48.

13. *Müller, J.*—Untersuchungen über die Eingeweide der Fische. Abhandlungen der Kgl. Akad. der Wissenschaften zu Berlin, 1843, pp. 109-170. In this paper is announced the discovery that the red corpuscles of myxine are, in the adult condition, oval, while the developing corpuscles are circular. p. 119. The statement is so important, in consideration of the statements by many comparative anatomists, that it is here given: "Die frische untersuchten Blutkörperchen der *Myxine glutinosa* sind elliptisch, platt wie gewöhnlich und mit einem rundlichen Nucleus versehen, dessen Oberfläche ein granulirtes Ansehen hat. Die jüngeren Blutkörperchen geben sich durch ihre blassere Farbe und ihren runden Umfang zu erkennen."

14. *Owen, R.*—Comparative Anatomy and Physiology of Vertebrates. 3 vols. London, 1861-1868. In Vol. I, p. 463, he says: "Cor-



puscles nearly circular in the lamprey and ammocœtes (that is the larva); in myxine they are elliptical."

15. *Parker, W. N.*—Elements of the Comparative Anatomy of Vertebrates: adapted from the German of R. Wiedersheim. London, 1886. It is stated that the red corpuscles of all vertebrates below mammals are *bi-convex*. The corpuscles of cyclostomes are circular, p. 268. See under 13 for myxine.

16. *Shipley, A. E.*—On Some Points in the Development of *Petromyzon fluviatilis*. *Quarterly Journal of Microscopical Science*, Vol. XXVII (1886-7), pp. 325-370. "The blood-corpuscles are of only one kind, large, oval, disc-like structures, with a well-marked nucleus," p. 343.

17. *Thompson, D'Arcy W.*—Note on the Blood-Corpuscles of the Cyclostomata. *Ann. and Mag. Natural History*, Vol. XX (1887), pp. 231-3. *Anat. Anz.* Bd. II, pp. 630-632. Repeats the statement of Shipley that the corpuscles of the larva are oval, and adds: "But the noteworthy point now is, that myxine possesses red corpuscles similar to those, not of the adult, but of the larval lamprey, which in many ways it resembles otherwise." As all observers, except Shipley, find the red corpuscles of lampreys at all ages circular in outline, any morphological conclusions like the above do not seem of extreme value.

18. *Wagner, R.*—Beitr. zur Vergleichenden Physiologie. Bd. ii, 1838. *Nachträge zur Vergl. Physiol. des Blutes*, p. 13. First announcement that the red blood-corpuscles of adult and larval lamprey eels are circular and bi-concave.

19. *Weber et Souchard.*—De la Disposition en Piles qu' Affectent les Globules Rouges du Sang. *Arch de Phys. Normal et Path.* 1880, pp. 521-531. Figures and describes rouleaux in the vessels of the mesentery of a living dog.

20. *Welcker, H.*—Grösse, Zahl, Volum, etc., der Blutkörperchen. *Zeit. F. Ratl, Medicin*, 3d Reihe, XX Bd. See note to table of measurements, above.

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